Figure 4.20 – HEPA filter mounting frame with clamps

neoprene prevent proper adhesion of the gasket to the filter case.

Filter units and adsorber cells must be clamped to the mounting frame with enough pressure to enable the gasket to maintain a reliable seal when subjected to vibration, thermal expansion, frame flexure, shock, overpressure, and widely varying conditions of temperature and humidity that can be expected in service. Clamping devices must function easily and reliably after long exposure to hostile environments. In addition, they must be capable of easy operation by personnel dressed in bulky protective clothing, gloves, and respirators (or full-face gas masks) while working in close quarters. Experience has shown that a simple nut-and-bolt system gives satisfactory service under these conditions. Nut-and-bolt clamping, however, entails removal and handling of a large number of nuts, and this procedure can be a problem during a filter change in a highly radioactive system. However, clamping systems that provide the required torque and gasket compression without loose parts are highly recommended. Any system that achieves the desired clamping torque is acceptable. **FIGURES 4.21 and 4.22** are examples of a HEPA filter clamping system that does not utilize loose parts. Examples of Type II adsorbent filter clamping systems are shown in **FIGURE 4.23**. Eccentric, cam-operated, over-center, or spring-loaded latches and other quick-opening latches such as the window latch design

Figure 4.21 – HEPA mouting frame with spring-load design filter hold-downs

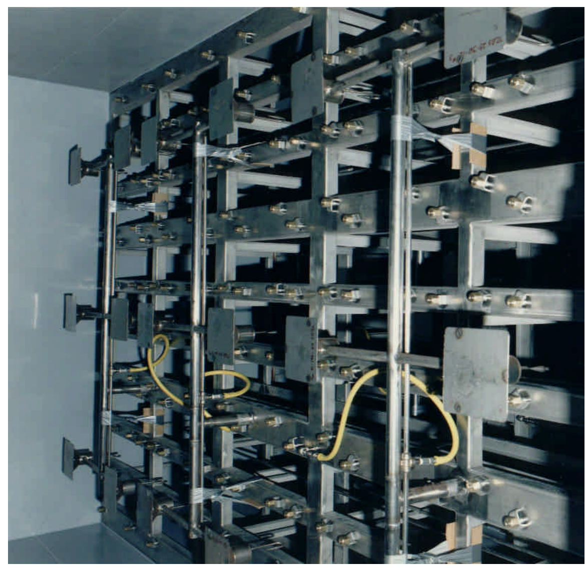


Figure 4.22 – Absorber mounting frame with test section manfold

are not recommended for clamping high-integrity components such as HEPA filters and adsorber cells.

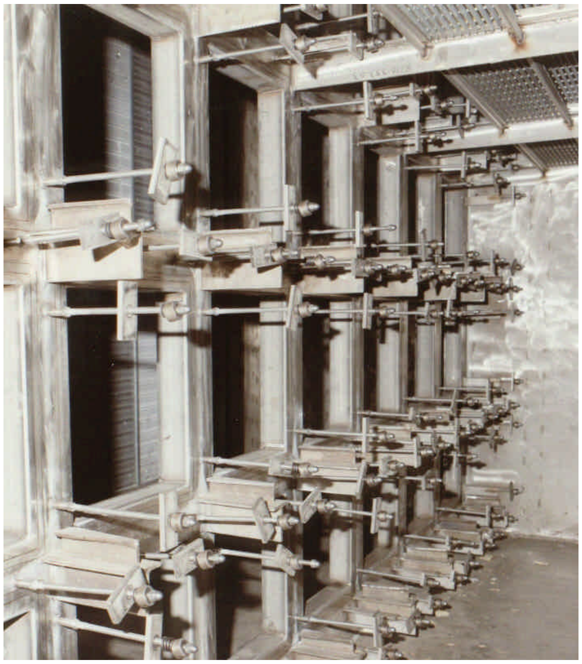


Figure 4.23 – HEPA filter mounring frame with spring-loaded hold-down clamps

Magnitude and uniformity are major requirements for filter and adsorber clamping systems. At least four and preferably eight pressure points are required for HEPA filters and demisters. Individual clamping of each filter unit is preferred. Shared clamping in which holding clips (or bolts) bear on two or more adjacent filters or adsorber cells has been widely used because it is less expensive than individual clamping and requires manipulation of fewer loose items within the confines of the housing during a filter change. However, shared clamping limits the ability to adjust or replace individual filters in the bank without upsetting the seals of adjacent units. In the improved system shown in FIGURE 4.20, no clip bears on more than two filter units, and the seals of only four surrounding filters are upset when replacing a filter unit. The clamping systems shown in FIGURES 4.19, 4.20, and 4.26 have the advantage that clips and nuts do not have to be removed to replace filters, since the clips can be rotated out of the way after the nuts have been loosened. The pressure distribution frame shown in **FIGURE 4.24** is not recommended, however, because of problems encountered in compression of the filter gasket. Although this type of clamping system has been used with good success in nuclear and non-nuclear applications, many in-place test personnel object to it because of the extensive leak-chasing often required before a satisfactory in-place test can be achieved. Leak-chasing occurs when, on adjusting or replacing one filter, the seals of surrounding filters are upset, resulting in new leaks that have to be corrected. This process is time-consuming, costly, and, when conducted in a contaminated housing, can result in lengthy exposure of personnel. In FIGURE 4.23, no clip bears on more than one filter unit.

Because of their weight, eight pressure points are desirable for clamping Type I (pleated-bed) adsorber cells. For clamping Type II (tray-type) cells, two pressure points on the top and two on the bottom edges of the front plate are needed for proper sealing, with individual clamping as shown in FIGURE 4.20. Clamping on the short sides only is not adequate. As FIGURE 4.20 shows, captive nuts reduce the number of loose items that must be manipulated within the confines of the filter housing during filter or adsorber replacement, but they must be prevented from rotation when positioned for withdrawal of the filter.

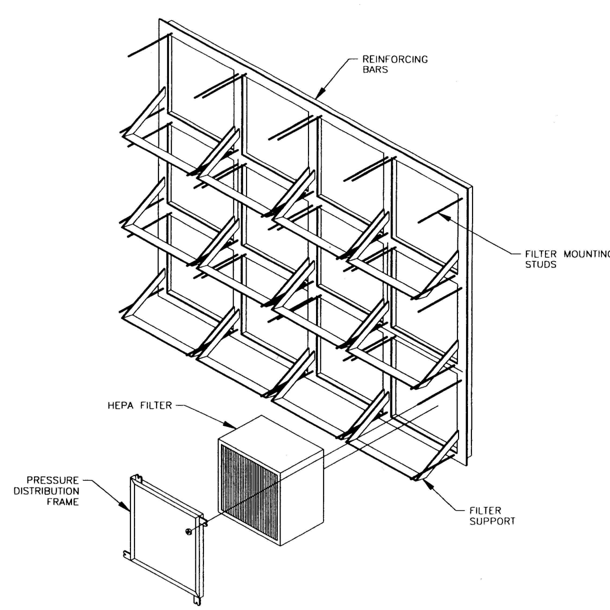


Figure 4.24 – HEPA filter mounting frame

Figure 4.25 – HEPA filters mounting frame. Blanking plate installed for filter change

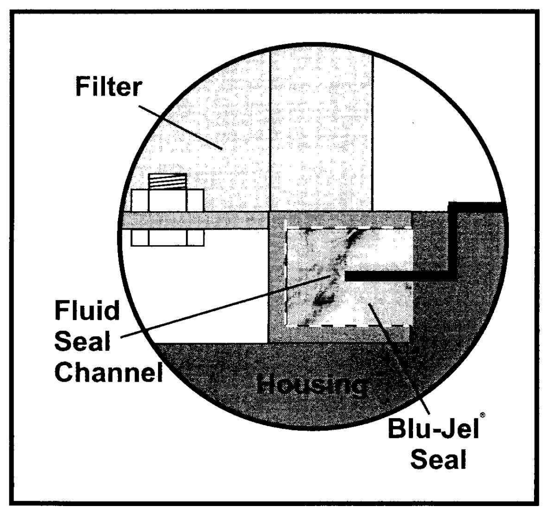
The minimum bolt size recommended for individually clamped filters is 3/8-16-UNC, but 1/2-11-UNC or 5/8-11-UNC bolts are less prone to damage. For Type I adsorbers, 5/8-11-UNC bolts are necessary.

The nuts and bolts of the clamping system must be made of dissimilar materials to prevent galling and seizing. Bolting materials and clips must be corrosion-resistant. Stainless steel (300 series) bolts with brass nuts are frequently used. Springs, if used, should also be made from a PPH grade of stainless steel if they are to resist corrosion and relaxation over a period of service.

The design knife-edge type of framing and sealing (**FIGURE 4.27**),[17] employs a special cross-section-extruded- framing member which presents a knife-edge-sealing surface to the filter element. The filters have a channel filled with a nonflowing, nonvulcanizing, silicone polymer around the sealing edge that fits into the knife edge of the mounting frame to form a positive seal between filter and frame. Rigidity of the mounting frame is not a consideration, since frame flexure cannot affect the seal or the filter. The clamping pressure needs to be sufficient only to hold the filter unit in place. If the filters are installed on the downstream side of the frame, clamping must be sufficient to resist displacement of the filter under normal operating filter resistance and the pressures produced by shock loadings in the system.

Figure 4.26 – Filter hold-down – Torque spring type

The Fluid Seal



A knife edge in the filter housing mates into a fluid-filled channel provided on the filter. Flanders invented the fluid seal in response to requirements for an absolute seal in the most critial applications. In most cases, fluid seal filters are also easier and quicker to change out than gasketed filters.

Figure 4.27

4.4.7 FILTER SUPPORT

A cradle or other support for the filter element as it is moved into position on the frame is a desirable feature from a maintenance standpoint. The cradle should not obscure any more of the filter-to-frame interface than necessary to avoid interference with inspection as the filter is installed. The support shown in FIGURES 4.23 and 4.24 is better because it obscures less of the gasket-frame interface. In some installations, filters have been supported on the bottom clamping bolts, a practice that risks damage to the threads of the clamping bolts and is not recommended.

4.4.8 SIZE AND ARRANGEMENT OF FILTER AND ADSORBER BANKS

The size (nominal airflow capacity) and orientation of filter banks (vertical or horizontal), the location of filters on the bank (upstream or downstream side), and the floor plan and height of the bank all affect the reliability, performance, maintainability, and testability of the air cleaning system. Savings gained by designing for minimum space and materials can be wiped out many times over by the higher operational, maintenance, and testing costs that will result from higher pressure drop and cramped working space in the filter housing.

4.4.9 VERTICAL FILTER BANKS

Vertical banks with horizontal airflow are preferred in contaminated exhaust systems because the filters are more favorably oriented with respect to ease of handling, mechanical strength of the filters, and collection of condensate. On the other hand, the pleats of Type I adsorber cells and the beds of Type II cells must be installed horizontally to avoid adsorbent settling in the cells. Before designing a horizontal filter bank with vertical airflow, filter/adsorber components should be validated for performance in this application/design. In addition, the design should include provisions for filter installation and removal.

4.4.10 LOCATION OF FILTERS ON MOUNTING FRAME

No clear-cut preference can be justified for mounting filters on either the upstream or the downstream side of the mounting frame; both methods have been used successfully and the advantages and disadvantages of each are listed below.

4.4.10.1 UPSTREAM MOUNTING OF FILTERS

Advantages

- The filters are withdrawn into and handled within the contaminated side of the system during a filter change. No contaminated materials are brought into the clean side of the system, so there is more complete separation of the clean and dirty sides of the system.
- Airflow tends to load the filter gaskets during operation, so there is less chance of leaks.

Disadvantages

- Personnel have to work within a potentially contaminated zone during a filter change.
- It is possible that contamination can be tracked or carried out of the contaminated zone by workmen unless there the filter change is carefully planned and executed.
- The filter clamping devices are located in the dirty side of the system where they are most exposed to corrosion and dirt.

4.4.10.2 DOWNSTREAM MOUNTING OF FILTERS

- **Advantages**
- Filters are withdrawn into and handled within the clean side of the system, thereby reducing the likelihood of tracking or carrying contamination into the building during a filter change.
- Personnel are not required to work in a highly contaminated portion of the housing during a filter change.

- Filter clamping devices are located on the clean side of the system where they are less subject to corrosion.
- Leak-scanning of installed filters is more sensitive. If there are gasket or casing leaks, the driving force of air entering the filter forces the test aerosol through the leak, and it is readily detected. With upstream mounting, on the other hand, any test aerosol that goes through a leak in a gasket or filter case mixes with the air and test aerosol passing through the opening in the mounting frame, thus obscuring the leaks. Although the existence of a leak may be disclosed by a test, the location of the leak cannot be easily determined by probing.
- Only the upstream face of the filter is contaminated during operation. The outer surfaces of the filter case and the downstream face of the filter pack are not usually contaminated.
- <u>**Disadvantages**</u>
- Filter gaskets tend to be unloaded by air pressure during operation, thus increasing the likelihood of gasket blowby.
- The contaminated filters must be withdrawn into the clean side of the system in a filter change. This second disadvantage can be offset by "fixing" the contaminated dust by spraying the upstream side of the filter pack with paint or acrylic spray or by taping cardboard over the upstream face of the filter. However, this procedure requires personnel to enter the contaminated chamber of the housing, and the possibility still exists of dislodging contaminated dust into the clean side of the system, either from the filter itself or from the edges of the frame opening (which is exposed to contaminated air during operation).

Filters have been mounted on both sides of a mounting frame in some installations. A cardinal rule in contaminated exhaust systems is that no credit is granted for untested and untestable filters. Therefore, although double mounting may provide two sets of filters, the operator cannot take credit for two-stage filtration or series redundancy.

4.4.11 SIZE OF BANKS

A nominal limit of 30,000 cfm is recommended by DOE and the U.S. Nuclear Regulatory Commission (USNRC) for any single filter or adsorber bank. For larger systems, this limit requires the system to be segmented into two or more smaller subsystems, each contained in an individual housing and having an installed capacity of 30,000 cfm or less. The purpose of this requirement is to facilitate maintenance and in-place testing, to improve control in the event of a system upset, and to enhance the reliability of the total system. A 30,000-cfm bank is about the largest that can be tested in-place conveniently. In addition, by breaking the system into two or more air cleaning units, testing and filter replacement can he conducted in one unit while the other unit remains on line. USNRC Regulatory Guide 1.52 recommends such redundancy for ESF air cleaning systems in reactors.[18] The designer may also choose to segment a system into units of substantially less than 30,000 cfm when redundancy is desired to achieve advantages of control, maintainability, and testability.

4.4.12 ARRANGEMENT OF BANKS

Spatial arrangement of filters on a mounting frame influences operating performance and maintenance. If one were to specify twelve 1,000-cfm filters (24- by 24- by 11.5 in.) arranged in a 6-wide by 2-high array, it would create a difficult installation and maintenance situation because personnel would be forced to crawl or work stooped over in the filter house. On the other hand, arranging the same bank in a 2-wide by 6-high array would make it impossible for one to reach the upper filters without bringing ladders or temporary scaffolding into the housing (a major source of filter damage) or providing a permanently installed work gallery. If the filters were arranged 3-wide by 4-high, there would still be the problem of access to the top tier of filters. The best solution is to arrange the filters in a 4-wide by 3-high array. For similar reasons, the best arrangement for a 600-cfm system would be a 2-wide by 3-high array.

Where possible, banks should be laid out in an array of three filters high or nine Type II adsorber cells high. When floor space is at a premium, the bank may be arranged with one 3-high array above another, with a service gallery between, as shown in FIGURES 4.7 and 4.8. Thus, an 18,000-cfm bank might be arranged in an array 6-wide by 3-high or 3-wide by 6-high, with a service gallery between the third and fourth tiers. The arrangement of a 24,000-cfm bank in a 6-wide by 4-high array would be undesirable. A better arrangement is an array 8-wide by 3-high or, if floor space is at a premium, two 4-wide by 3-high arrays, one above the other, separated by a service gallery. In no case should filter changing require the use of ladders or temporary scaffolding. To require a workman dressed in bulky protective clothing (with sight obscured by a respirator or gas mask and sense of feel dulled by double gloves) to manipulate a ladder or scaffold within the confines of a filter house is an open invitation to filter damage and personnel injury. Based on the 95th-percentile man,[19] the maximum height at which a man can operate hand tools effectively is 78 in., and the maximum load he can handle at a height of 5 ft or more is 40 lb.[20] Therefore, provision for access to the higher tiers of filters is necessary. In fact, ASME AG-1, Subarticle HA-4433,[26] requires that a permanent platform be installed to access filters to access filters above 6 ft.

Filter banks should be rectangular. The use of odd-shaped banks to limit installed filter capacity to calculated system airflow requirements increases construction costs significantly. By filling out the rectangle, construction costs will be less. In addition, if all nine spaces are filled with filters, operating costs may also be reduced because the additional filters permit operation at a lower flow rate per unit resulting in longer filter life and reduced filter-change frequency, as discussed in Chapter 2. For the purposes of laying out adsorber banks, three Type II (tray) adsorbers will fit vertically into the space occupied by one 24- by 24-in. HEPA filter.

4.4.13 FLOOR PLAN OF FILTER BANKS

Vertical banks may be arranged in a plane (**FIGURES 4.28 through 4.35**). Judicious layout of a bank can often reduce pressure losses in the system and bring about more uniform dust-loading of filters, thereby equalizing utilization of the filters installed in the bank. If the open side of a U-arrangement is centered on the fan inlet, for example, the distances from the filters to the fan are more or less equalized and the bank may in effect form an inlet box that enhances fan-inlet conditions and produces more uniform pressure drop across, and loading of, the filters. On the other hand, straight (plane) banks are safer from the standpoint of fire-spread than U-shaped or stepped arrangements.[22]